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Lake McDonald, Flathead County, Montana

National Eutrophication Survey, Corvallis, Oreg

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May 77

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REPORT

ON

LAKE MCDONALD

FLATHEAD COUNTY

MONTANA

EPA REGION VIII

WORKING PAPER NO. 797

WITH THE COOPERATION OF THE

MONTANA DEPARTMENT OF HEALTH & ENVIRONMENTAL SCIENCES

AND THE

MONTANA NATIONAL GUARD

MAY, 1977

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16 ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17 KEY WORDS AND DOCUMENT ANALYSIS

a DESCRIPTORS	b IDENTIFIERS/OPEN ENDED TERMS	c COSATI Field/Group
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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§304(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

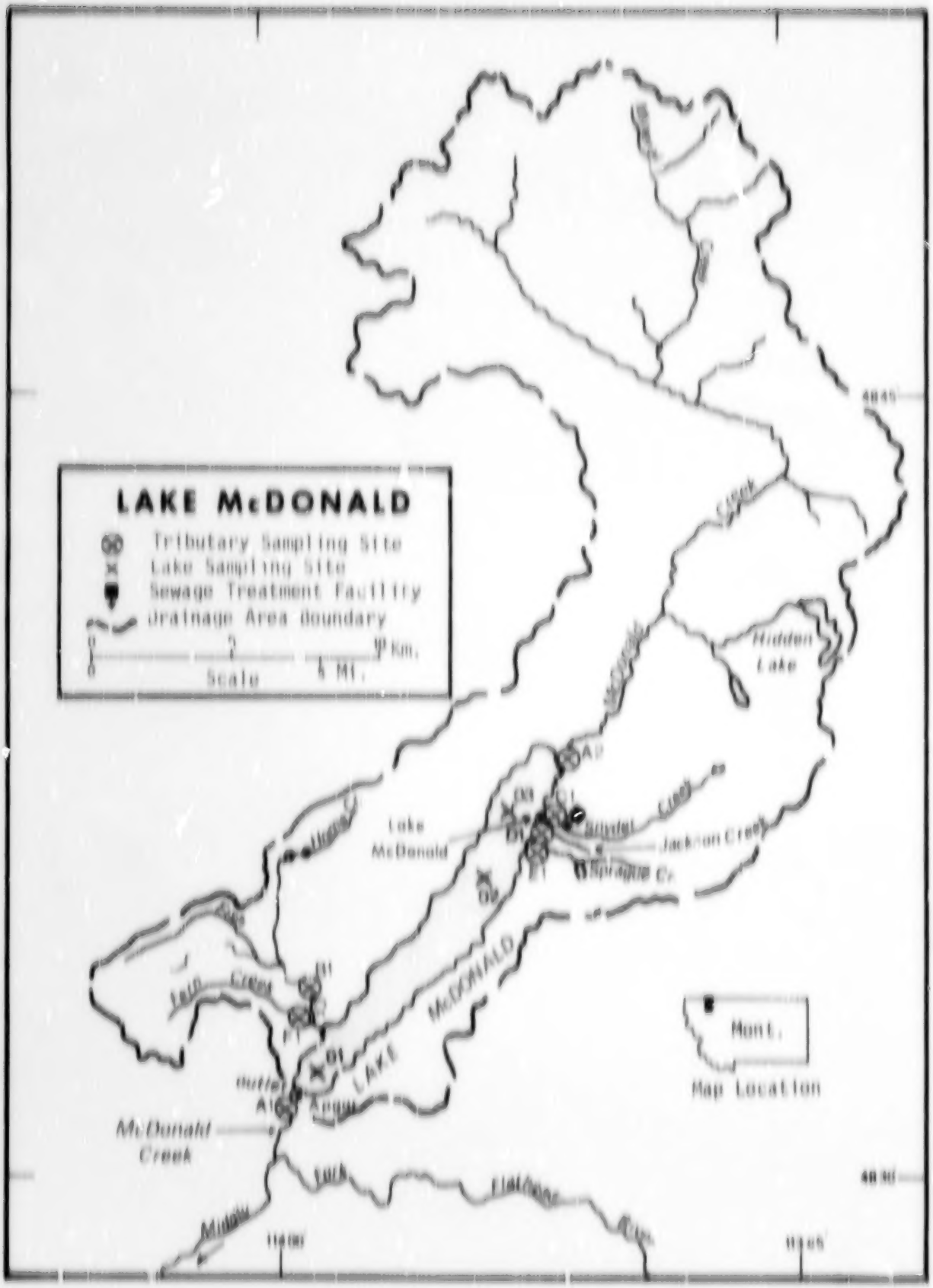
The staff of the National Eutrophication Survey (Office of Research & Development, U.S. Environmental Protection Agency) express sincere appreciation to the Montana Department of Health and Environmental Sciences for professional involvement, to the Montana National Guard for conducting the tributary sampling phase of the Survey, and to those Montana wastewater treatment plant operators who voluntarily provided effluent samples.

The staff of the Water Quality Bureau provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General John E. Woodrick, the Adjutant General of Montana, and Project Officer Major William Yeager, who directed the volunteer efforts of the Montana National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY
STUDY LAKES AND RESERVOIRS
STATE OF MONTANA

LAKE NAME	COUNTY
Canyon Ferry	Broadwater, Lewis and Clark
Clark Canyon	Beaverhead
Flathead	Flathead, Lake
Georgetown	Deer Lodge, Granite
Hebgen	Gallatin
Koocanusa	Lincoln, MT; British Columbia, Can.
Mary Ronan	Lake
McDonald	Flathead
Nelson	Phillips
Seeley	Missoula
Swan	Lake
Tally	Flathead
Tiber	Liberty, Toole
Tongue River	Big Horn
Whitefish	Flathead
Yellowtail	Carbon, Bighorn, MT; Bighorn, WY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Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
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2
4 Km.
0
Scale
1 Mi.
Hidden Lake
Lake McDonald
Jackson Creek
McDONALD
LAKE
Mont.
Map Location
McDonald Creek

LAKE McDONALD

STORET NO. 3008

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Lake McDonald is oligotrophic. It ranked second in overall trophic ...ility when the 15 Montana lakes and reservoirs sampled in 1975 were compared using a combination of six parameters*. None of the other water bodies had less median total phosphorus, median dissolved orthophosphorus, or mean chlorophyll a; 13 had less and one had the same median inorganic nitrogen; and none of the others had greater mean Secchi disc transparency.

Survey limnologists noted some submerged macrophytes in July.

B. Rate-Limiting Nutrient:

The algal assay results indicate the lake was phosphorus limited in June. The lake data indicate phosphorus limitation in July as well.

C. Nutrient Controllability:

1. Point sources--It is calculated that known point sources contributed only 2.1% of the total phosphorus load received by Lake McDonald during the sampling year. The Lake McDonald Lodge wastewater treatment plant was the major contributor (1.4%).

* See Appendix A.

In May of 1976, nutrients from these sources were eliminated by diversion to the new Lake McDonald Valley wastewater treatment plant with effluent disposal by spray irrigation outside the Lake McDonald drainage basin (Gingery, 1976).

During the sampling year, the lake received a total phosphorus loading amounting to about 81% of that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a permissible loading (see page 12). Therefore, elimination of the known point source loads may not result in significant improvement in the water quality in the lake. Nevertheless, minimization of phosphorus inputs to the lake will provide protection for the existing trophic condition.

2. Non-point sources--It is estimated that non-point inputs accounted for about 98% of the total phosphorus load to the lake during the sampling year. McDonald Creek contributed 79% of the total load, and the three remaining gaged tributaries collectively contributed 8.1%.

The phosphorus export rates of McDonald and Snyder creeks were relatively high compared to the 8 kg/km^2/year mean rate of 37 Montana streams gaged and sampled during the Survey. The higher rate of Snyder Creek may have resulted from underestimation of the point-source load, but the cause of the higher rate of unimpacted McDonald Creek is not obvious since the entire drainage of the creek is within Glacier National Park.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 32.63 kilometers^2.

2. Mean depth: 45.7 meters.

3. Maximum depth: 134.1 meters.

4. Volume: 1,491.191 x 10^6 m^3.

5. Mean hydraulic retention time: 3.2 years.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
McDonald Creek	283.9	12.650
Fish Creek	39.6	0.700
Snyder Creek	13.8	0.472
Sprague Creek	16.5	0.165
Minor tributaries & immediate drainage -	57.5	0.970
Totals	411.3	14.957

2. Outlet -

McDonald Creek	443.9**	14.770

C. Precipitation***:

1. Year of sampling: 73.6 centimeters.

2. Mean annual: 75.3 centimeters.

† Table of metric conversions--Appendix B.
†† Gingery, 1976.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Lake McDonald was sampled two times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at three stations on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depth sampled at each station was 61.0 meters.

The sampling results are presented in full in Appendix D and are summarized in the following table.

[illegible] OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR [illegible]
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PARAMETER	1ST SAMPLING : [illegible]			2ND SAMPLING : [illegible]			3RD SAMPLING : [illegible]		
	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN
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* [illegible]
[illegible]

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
06/01/75	1. Dinobryon sp.	56
	2. Gymnodinium sp.	14
	Total	70
07/28/75	1. Cyclotella sp.	57
	Total	57

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
06/01/75	1	0.4
	2	0.4
	3	3.4
07/28/75	1	0.6
	2	0.5
	3	0.5

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l dry wt.)
Control	0.005	0.157	0.5
0.050 P	0.055	0.157	6.3
0.050 P + 1.0 N	0.055	1.157	22.0
1.0 N	0.005	1.157	0.3

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Lake McDonald was relatively low at the time the sample

was collected (06/01/75). Also, a significant increase in yield with the addition of phosphorus alone indicates the lake was phosphorus limited at that time. Note that the addition of nitrogen alone resulted in a yield which was not significantly different from that of the control.

The lake data indicate phosphorus limitation both sampling times (the mean inorganic nitrogen/orthophosphorus ratios were at least 25/1 in June and 14/1 in July, respectively).

IV. NUTRIENT LOADINGS
(See Appendix I for data)

For the determination of nutrient loadings, the Montana National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of May and June when two samples were collected. Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Montana District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("//" of U.S.G.S.) were estimated using the means of the nutrient loads, in kg/km^2/year, at stations B-1 and E-1 and multiplying by the // area in km^2.

The operator of the Lake McDonald Lodge wastewater treatment plant did not participate in the Survey, and nutrient loads from the plant were estimated using 1.134 kg P and 3.401 kg N/capita/year. The oper-

* See Working Paper No. 175.

ation of this plant, which previously was from May through September each year (the peak visitation period at Glacier National Park), was discontinued in September, 1975. Sewage from the lodge is now treated at the new Lake McDonald Valley wastewater treatment plant along with wastes previously treated in septic tanks. The new plant was initially opened in May of 1976 and will operate on a May through September basis (Gregory, op. cit.).

A. Waste Sources:

1. Known municipal -

Name	Pop. Served	Treatment	Mean flow (m^3/d)	Receiving Water
Lake McDonald Lodge	282*	tr. filter	107**	Snyder Creek

2. Known industrial - None

* Estimate based on 94 rooms and three people per room.
** Estimated at 0.3785 m^3/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
McDonald Creek	7,495	78.9
Fish Creek	420	4.4
Snyder Creek	285	3.0
Sprague Creek	65	0.7
b. Minor tributaries & immediate drainage (non-point load) -	460	4.9
c. Known municipal STP's -		
Lake McDonald Lodge	135	1.4
d. Septic tanks* -	70	0.7
e. Known industrial - None	-	-
f. Direct precipitation** -	570	6.0
Total	9,500	100.0

2. Outputs -

Lake outlet - McDonald Creek 5,035

3. Net annual P accumulation - 4,465 kg.

* Estimate based on a population equivalent of 618 calculated from flow (at 0.3785 m^3/capita/day) at the Lake McDonald Valley STP; see Working Paper No. 175.

** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr.	% of total
a. Tributaries (non-point load) -		
McDonald Creek	347,325	78.8
Fish Creek	18,745	4.3
Snyder Creek	11,735	2.6
Sprague Creek	3,980	0.9
b. Minor tributaries & immediate drainage (non-point load) -	20,530	4.7
c. Known municipal STP's -		
Lake McDonald Lodge	400	0.1
d. Septic tanks* -	2,635	0.6
e. Known industrial - None	-	-
f. Direct precipitation** -	35,225	8.0
Total	440,075	100.0

2. Outputs -

Lake outlet - McDonald Creek	364,395

3. Net annual N accumulation - 75,680 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
McDonald Creek	26	1,221
Fish Creek	11	473
Snyder Creek	21	814
Sprague Creek	4	241

* Estimate based on a population equivalent of 618 calculated from flow (at 0.3785 m³/capita/day) at the Lake McDonald Valley STP; see Working Paper No. 175.
** See Working Paper No. 175.

f. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Jackson Creek	0.020	0.222
Fern Creek	0.014	0.867

f. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.29	0.14	13.5	2.3

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Lake McDonald:

"Dangerous" (eutrophic loading)	0.72
"Permissible" (oligotrophic loading)	0.36

V. LITERATURE REVIEWED

Gingery, Maurice M., 1976. Personal communication (lake morphometry; sewage collection and treatment systems in the vicinity of Lake McDonald). U.S. Natl. Park Serv., Glacier National Park, West Glacier, MT.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

APPENDIX B

PHYSICAL and CHEMICAL DATA

APPENDIX E

TRIBUTARY DATA

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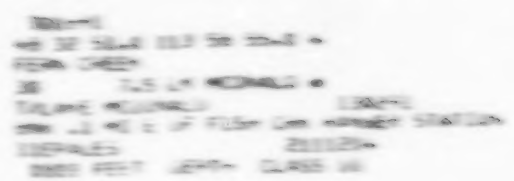

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